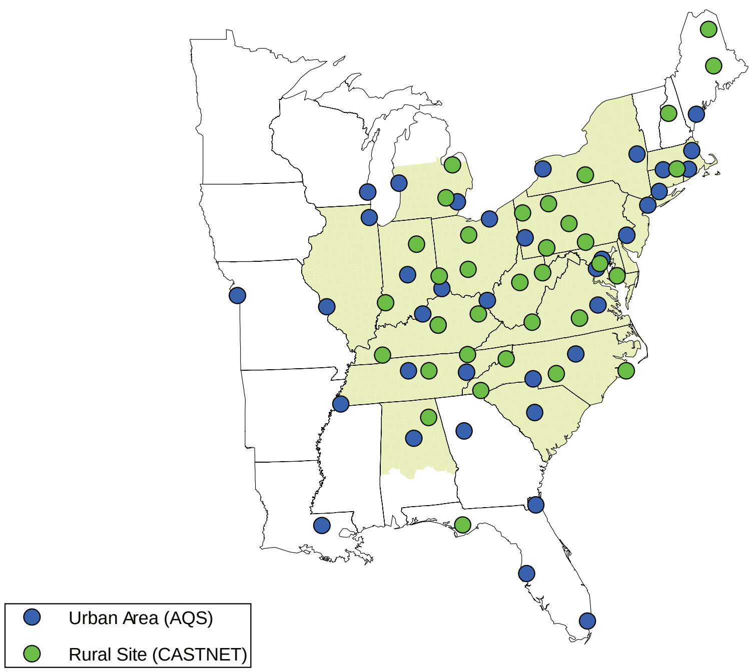
Section 3 — Environmental Results

To better understand how the NO_x Budget Trading Program (NBP) affects ozone, this section examines ozone air quality across the NBP states since 1997 and then looks at changes in ozone concentrations before and after implementation of the NBP. In addition, this section compares geographic patterns in ozone concentrations to reductions in nitrogen oxides (NO_x) emissions under the NBP. These analyses consider the impact of weather, because variations in weather conditions play an important role in determining ozone levels.

Ozone Monitoring Networks

For this report, EPA assembled data from 36 urban areas from the Air Quality System (AQS) and 35 rural sites from the Clean Air Status and Trends Network (CASTNET) to provide a more complete picture of air quality in the eastern United States (see Figure 10). EPA only used sites with sufficient meteorological and ozone data within each time period. For a monitor or area to be included in this analysis, 50 percent of the days for the ozone season had to have complete and valid data.

Figure 10: Location of Urban and Rural Ozone Monitoring Networks

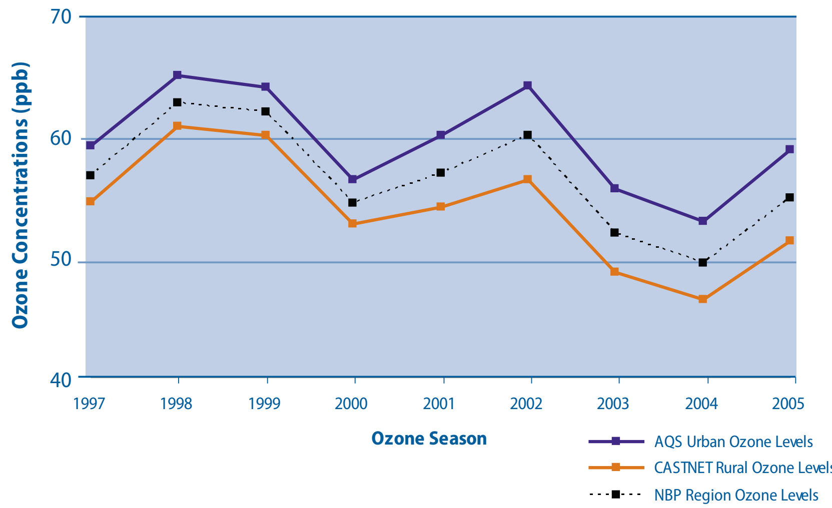


Notes:

- States participating in the NBP in 2005 are shaded in green (referred to as the "NBP region").
- Urban areas represent multiple monitoring sites. Rural areas represent single monitoring sites.
- For more information on AQS, visit <www.epa.gov/ttn/airs/airsaqs>. For more information on CASTNET, visit <www.epa.gov/castnet>.

Source: EPA

Figure 11: Trends in Seasonal Average 8-Hour Ozone Concentrations in the NO_x Budget Trading Program Region (Not Adjusted for Meteorology)



Note: Data presented in this figure are unweighted averages of 8-hour daily maximum ozone concentrations during the ozone season for sites within the NBP region, shaded in green in Figure 10.

Source: EPA

General Trends: Changes in Eastern Ozone Concentrations since 1997

Figure 11 shows trends in the "seasonal average" 8-hour ozone concentrations in the NBP region from 1997 to 2005, showing the variability over time in measured ozone concentrations at urban and rural sites. The seasonal average ozone concentration is the average of daily maximum 8-hour ozone concentrations from May 1 through September 30. On average, 2005 ozone concentrations in the NBP region remain below 2002 levels, but are higher than in 2004 (not adjusted for meteorology). In general, weather conditions were more conducive to ozone formation in 2005 than in 2004.

Figure 11 also shows that on average, ozone in rural areas is lower than ozone in urban areas but follows a similar trend. These results provide a seasonal average for NBP states and do not show variations in ozone concentrations for specific urban or rural areas. Although urban and metropolitan areas typically experienced higher ozone concentrations, non-urban areas can also experience high ozone levels due to transport and local emission sources (e.g., mobile sources).

For example, the National Park Service reported that based on a 3-year average of the fourth highest daily maximum 8-hour ozone concentration (in parts per billion, or ppb) for the years 2002 to 2004, three National Park Units in the eastern United States (Acadia, Cape Cod, and Great Smoky Mountains) experienced high ozone concentrations that exceeded 85 ppb.[3]

Ozone Changes after Adjusting for Meteorology

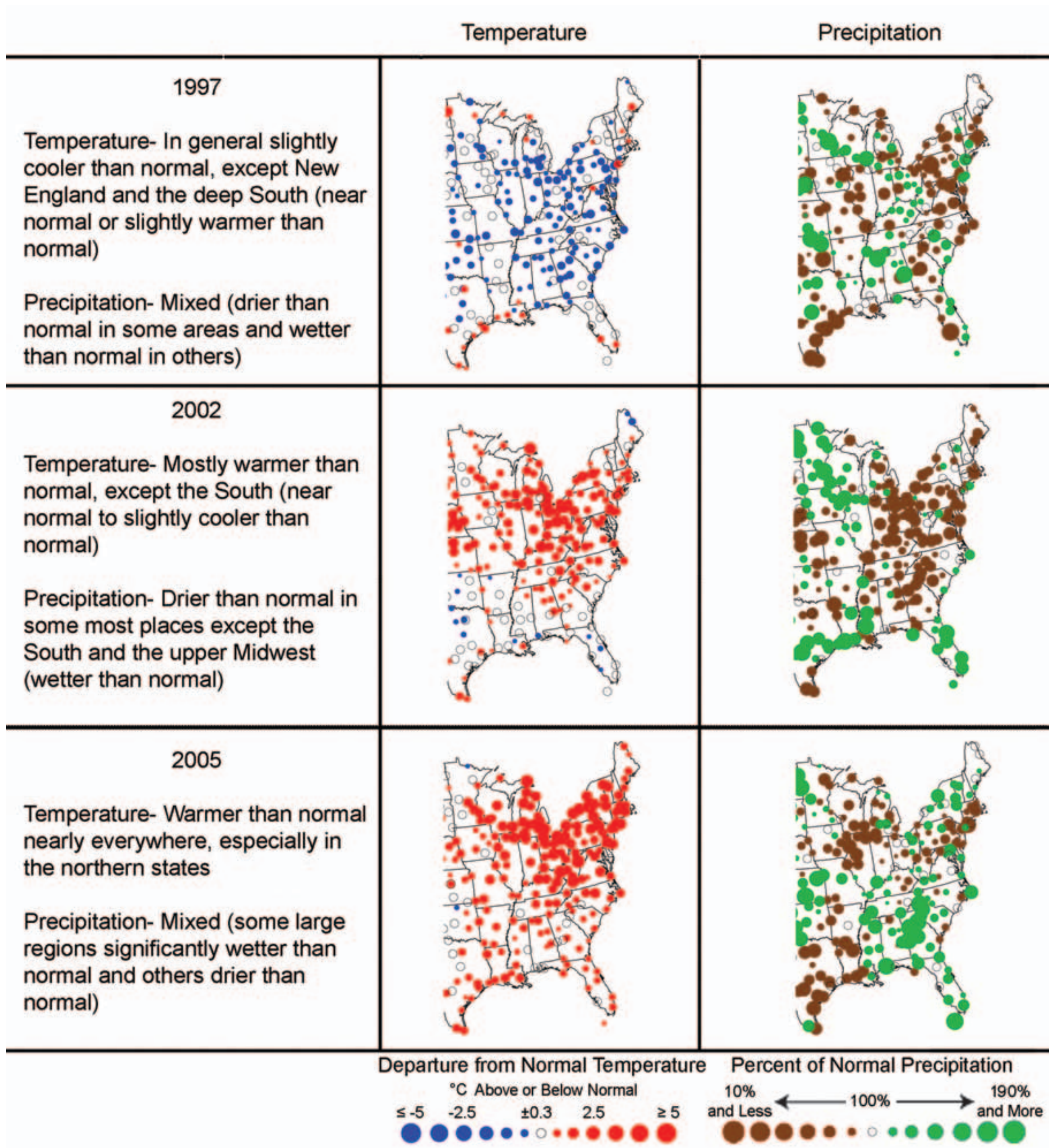
Variations in weather conditions play an important role in determining ozone levels. EPA uses a statistical model to account for the weather-related variability of seasonal ozone concentrations to provide a more accurate assessment.[4]

[3] National Park Service Air Resources Division. "Annual Data Summary, 2004 Gaseous Pollutant Monitoring, Program Ozone, Sulfur Dioxide, Meteorological Observations." U.S. Department of the Interior. <www2.nature.nps.gov/air/pubs/pdf/ads/2004/GPMP-XX.pdf>.

[4] Cox, William M. and Shao-Hang Chu. (1996). "Assessment of Interannual Ozone Variation in Urban Areas from a Climatological Perspective." *Atmospheric Environment*, 30.14, 2615-2625.

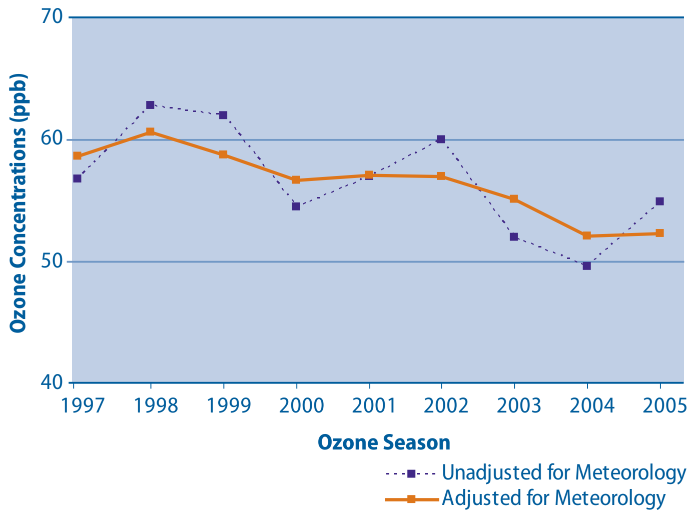
Meteorology Matters

The graphics below show how the summers of 1997, 2002, and 2005 deviate from normal summer conditions for temperature and precipitation (a surrogate for humidity). Normal conditions are determined by averaging 30 years of temperature and precipitation data (1971 to 2000) at each site for June through August. The information presented below is useful in evaluating the ozone forming potential for a particular ozone season.



Source: National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center <http://www.ncdc.noaa.gov/oa/climate/research/2002/CMB_prod_us_2002.html>

Figure 12: Seasonal Average 8-Hour Ozone Concentrations in the NO_x Budget Trading Program Region before and after Adjusting for Weather



Note: Data presented in this figure are unweighted averages of 8-hour daily maximum ozone concentrations during the ozone season for sites within the NBP region, shaded in green in Figure 10.

Source: EPA

This report uses an assessment approach that accounts for the impacts of weather by normalizing weather variations to provide a better estimate of the underlying ozone trend and the impact of NO_x emission reductions. The resulting estimates represent ozone levels anticipated under typical weather conditions. This methodology and the ozone estimates were provided by EPA's Office of Air Quality Planning and Standards (OAQPS), Air Quality Assessment Division, www.epa.gov/airtrends.

Figure 12 shows trends in the seasonal average 8-hour ozone concentrations before and after adjusting for meteorology. The blue dotted line shows the trend in unadjusted, observed values at monitoring sites. The orange solid line illustrates the underlying ozone after removing effects of weather to provide a more accurate ozone trend for assessing changes in emissions. When comparing two years with significantly different weather conditions and ozone forming potential (e.g., 1997 vs. 2002), it is important to account for the variation caused by meteorology. For example, in general, lower temperatures depressed ozone formation in 1997 while higher temperatures increased ozone formation in 2002. Removing the effects of weather using this type of meteorological adjustment approach results in a higher than observed ozone estimate for 1997 and a lower than observed ozone estimate for 2002.

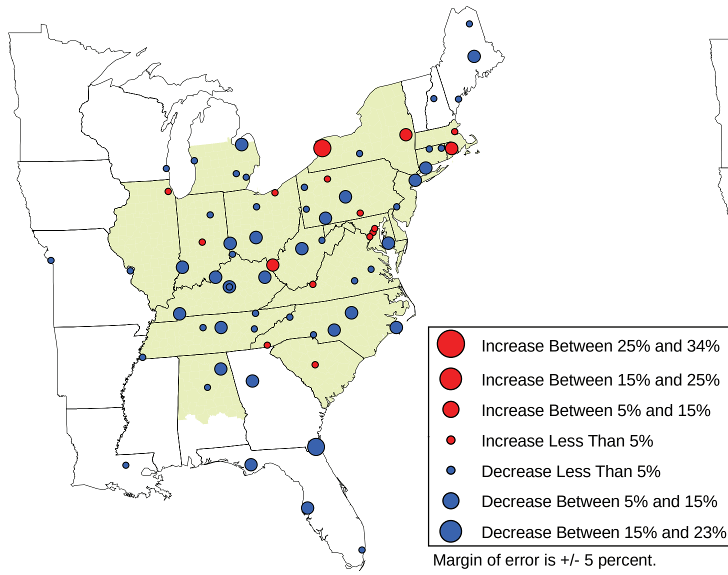
Ozone Changes: Focus on the NO_x Budget Trading Program

The 2004 NBP report, Evaluating Ozone Control Programs in the Eastern United States: Focus on the NO_x Budget Trading Program, concluded that the average reduction in ozone in the eastern United States between 1997 and 2002 was about 4 percent (adjusted for meteorology), compared with more than 10 percent between 2002 and 2004.[5]

Figures 13 and 14 illustrate changes in ozone concentrations between 1997 and 2002 and 2002 and 2005, after adjusting for meteorology. The average reduction in ozone in the NBP region between

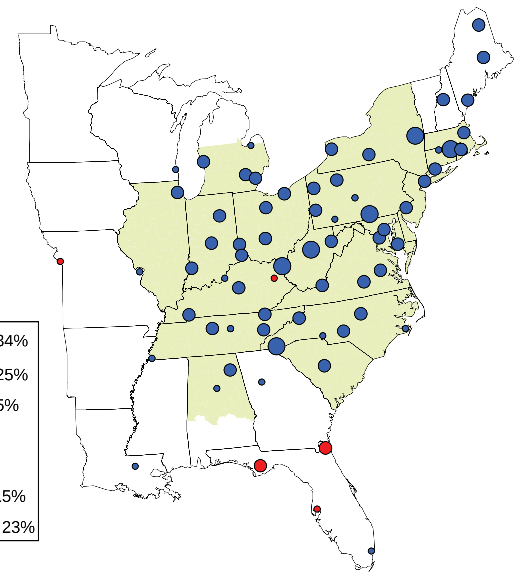
[5] "Evaluating Ozone Control Programs in the Eastern United States: Focus on the NO_x Budget Trading Program, 2004," <www.epa.gov/airmarkets/fednox>.

Figure 13: Percent Change in Seasonal 8-Hour Ozone, 1997 vs. 2002 (Adjusted for Meteorology)



Note: Shaded region shows areas affected under the NBP as of 2005.
Source: EPA

Figure 14: Percent Change in Seasonal 8-Hour Ozone, 2002 vs. 2005 (Adjusted for Meteorology)



Note: Shaded region shows areas affected under the NBP as of 2005.
Source: EPA

2002 and 2005 was about 8 percent. While, on average, there was no improvement in ozone in the NBP region between 2004 and 2005 (about 0.5 percent increase as shown in Figure 12), these results show that the majority of the ozone progress made between 2002 and 2004 was retained. In general, weather conditions in 2005 were similar to weather conditions in 2002 (i.e., both years had higher than average ozone forming potential). Before adjusting for meteorology, the average reduction in ozone between 2002 and 2005 was also about 8 percent.

Figure 15 shows the relationship between reductions in power industry NO_x emissions and reductions in ozone after implementation of the NBP. Between 2002 and 2005, there were decreases in ozone across all NBP states, with the largest reductions occurring in Connecticut, New York, North Carolina, Pennsylvania, and West Virginia. There were some increases in the southern United States, specifically in Florida (which is not in the NBP). Generally, there is a strong association between areas with the greatest NO_x emission reductions and downwind sites exhibiting the greatest improvement in ozone. This suggests that levels of transported NO_x emissions have been reduced in the eastern United States. While this report does not attribute all ozone reductions after 2002 to the NBP, it does show that the NBP has played a key role in reducing ozone concentrations.

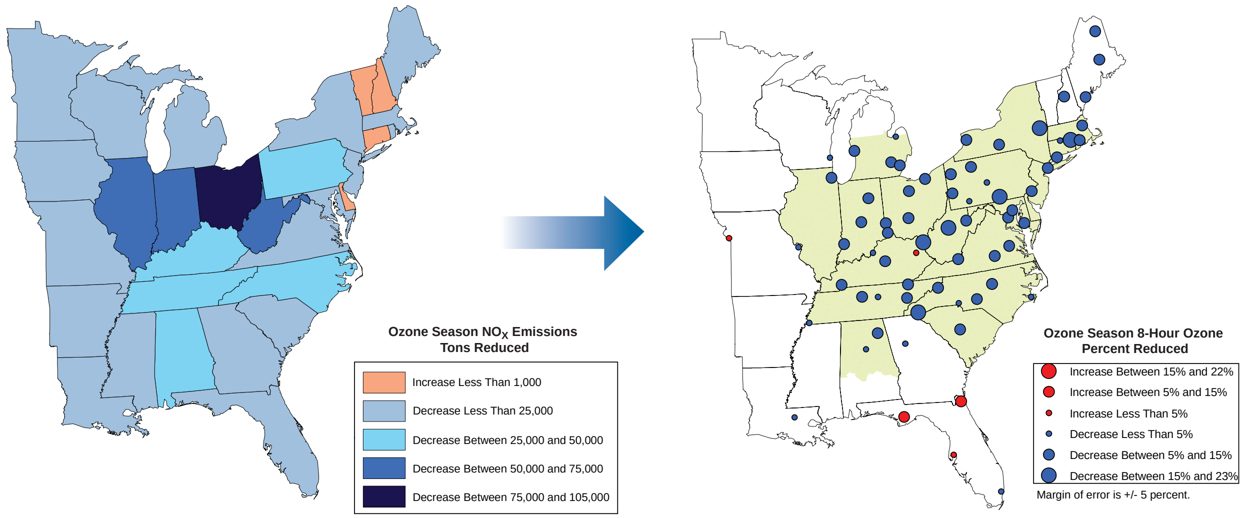
Other recent studies support the key findings of this report. Gégo et al. examined the effectiveness of the NO_x SIP Call by quantifying changes in daily maximum 8-hour ozone concentrations at monitoring sites in the eastern United States before (1997 to 1998) and after (2003 to 2004) implementation of the program.[6] The researchers primarily used CASTNET data for this analysis because these measurements are taken in rural areas where ozone production depends strongly on NO_x con-

[6] Gégo, Edith P, et. al. "Observation-based assessment of the impact of nitrogen oxides emissions reductions on ozone air quality over the eastern United States." *Journal of Applied Meteorology and Climatology*, special issue on the NOAA-EPA Golden Jubilee Symposium (submitted).

Figure 15: Reductions in Ozone Season Power Industry NO_x Emissions and 8-Hour Ozone, 2002 vs. 2005

Power Industry NO_x Emission Reductions

8-Hour Ozone, Adjusted for Meteorology



Note: From 2002 to 2005, Delaware (943 tons), New Hampshire (216 tons), Connecticut (76 tons), and Vermont (44 tons) show small increases in ozone season NO_x emissions.

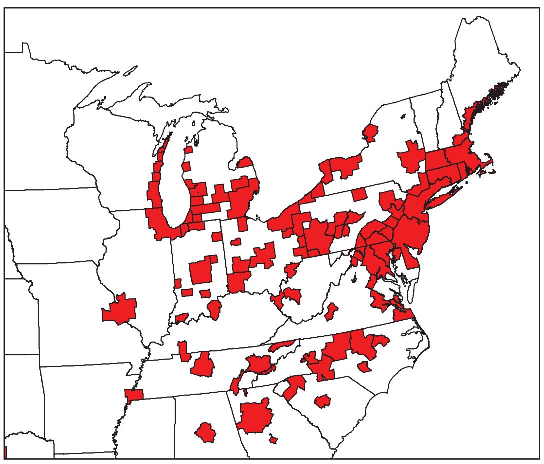
Source: EPA

centrations and is nearly independent of VOCs. After adjusting for meteorology, this study found that ozone concentrations are on average 13 percent less (ranging from 4 to 27 percent across all sites) than they were before the program. This study also used a back trajectory analysis and found that NO_x emission reductions in the Ohio River Valley resulted in substantial improvements in ozone air quality in downwind regions, especially east and northeast of the Ohio River Valley. This study concluded that the NO_x SIP Call has been effective in reducing interstate ozone transport and helping to improve ozone air quality in the eastern United States.

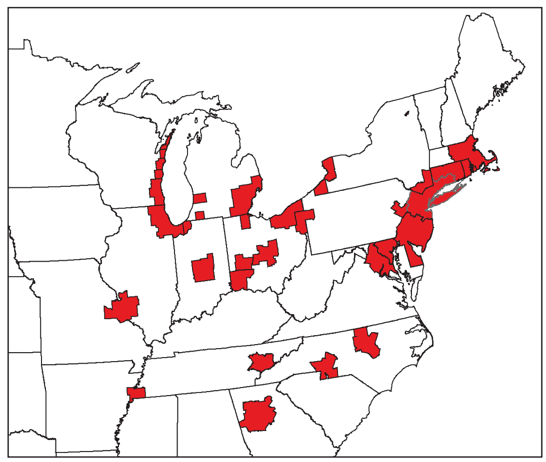
Improvements in 8-Hour Ozone Concentrations

In April 2004, based generally on 2001 to 2003 data, EPA designated 126 areas as nonattainment for the 8-hour ozone standard.[7] Of those areas, 103 are in this part of the eastern United States (see figures below) and are home to about 100 million people (US Census, 2000). Based on 2003 to 2005 data, 68 of the 103 areas (nearly 70 percent) either have ozone air quality that is better than the level of the 8-hour standard or meet the standard and have been redesignated to attainment. These improvements bring cleaner air to about 20 million people living in these 68 areas. Several of these areas have reviewed or are reviewing the requirements for redesignation as described in the Clean Air Act Section 107. Nearly 81 million people live in the remaining 31 areas in this part of the eastern United States. On average, ozone concentrations in these areas improved by 8 percent. Given that the only major relevant emission reduction that occurred after 2003 is the NBP, it is clear that the NBP is the major contributor to these improvements in ozone air quality.

8-Hour Ozone Nonattainment Areas, April 2004 (2001–2003 Air Quality Data)



Areas Remaining Above Standard (2003–2005 Air Quality Data)



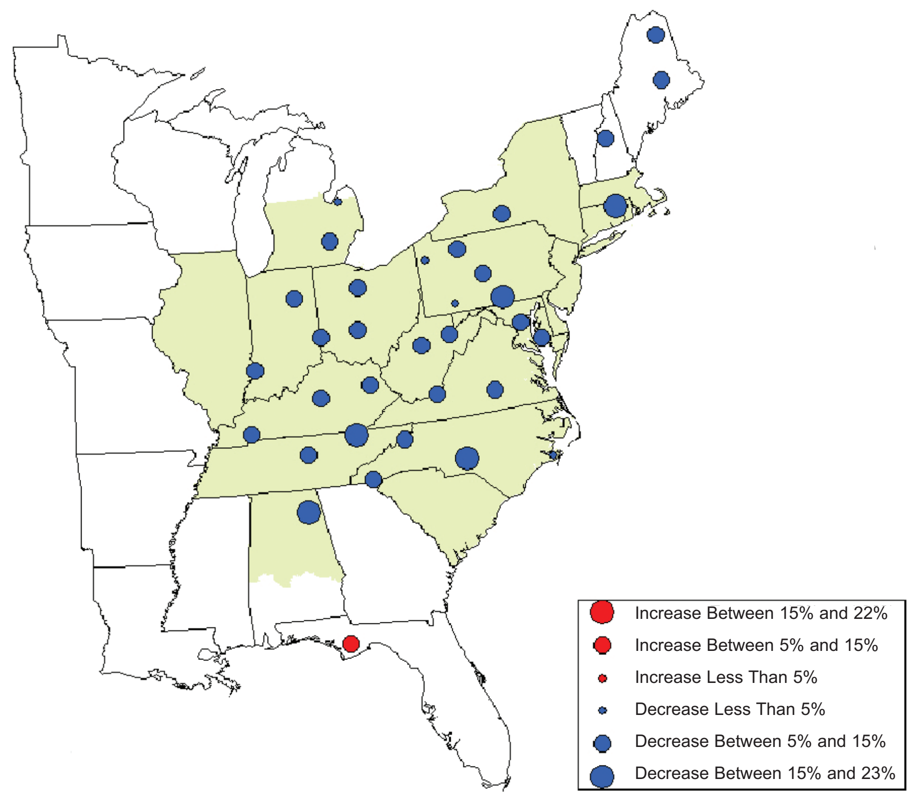
Note: Included on the maps, but excluded from the analysis, are four areas with incomplete data for 2003 to 2005 (Cass Co, MI; Dayton-Springfield, OH; Essex Co (Whiteface Mtn), NY; La Porte, IN).

[7] 40 CFR Part 81, Air Quality Designations and Classification for the 8-Hour Ozone National Ambient Air Quality Standards (NAAQS).

Space-Time Modeling Approach to Adjusting for Meteorological Influences on Ozone

There are different approaches to account for the influences of meteorology on ozone formation. This analysis presents results from a space-time modeling approach developed by EPA's Office of Research and Development. The method can provide the uncertainties surrounding ozone trend estimates and can be expanded to predict ozone at any location (e.g., even between ozone monitoring sites) and for any time period. The graphic below shows the percent change in seasonal average ozone concentrations at rural CASTNET sites using the space-time modeling approach. The results from this analysis corroborate the findings presented throughout the report; on average ozone concentrations have decreased across the eastern United States since 2002 (see figure below). By exploring and developing new methodologies for assessing ozone, EPA hopes to continue advancing assessment capabilities into the future.

Percent Change in Seasonal 8-Hour Ozone, 2002-2004



Source: EPA

Ozone Impacts on Forest Health

As with human health, EPA is concerned about the impacts of air pollution on ecological systems. Ground-level ozone-induced effects on trees and forests include reduced growth and/or reproduction and increased susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather). Ground-level ozone can also cause visible injury to leaves and foliage.

The United States Forest Service Forest Health Monitoring Program (FHM) uses visible foliar injury as an indicator that ground-level ozone is impacting trees and forests. The Ozone Biosite Index (see Table 3) was developed based on the proportion of damaged leaves and the severity of symptoms to the number of non-injured leaves within a defined forested area.[8] The Forest Service uses the Ozone Biosite Index to survey forested areas in the United States. The most recent data are presented as an average value from 1999 to 2002 (see Figure 16). This analysis shows that foliar injury occurred more extensively in the eastern United States than the western United States in this time period, especially in the Mid-Atlantic and the Southeast. These data show visible foliar injury before the NO_x emission reductions under the NBP took effect. Recent improvements in ozone due to emission control programs have occurred in many areas where forest ecosystems had experienced the most visible foliar injury from ozone exposure. While it will take time for forest ecosystems to respond to ozone improvements, as data become available (i.e., 2002 to 2005 data), EPA will continue to examine the impacts of ozone on forest indicators.

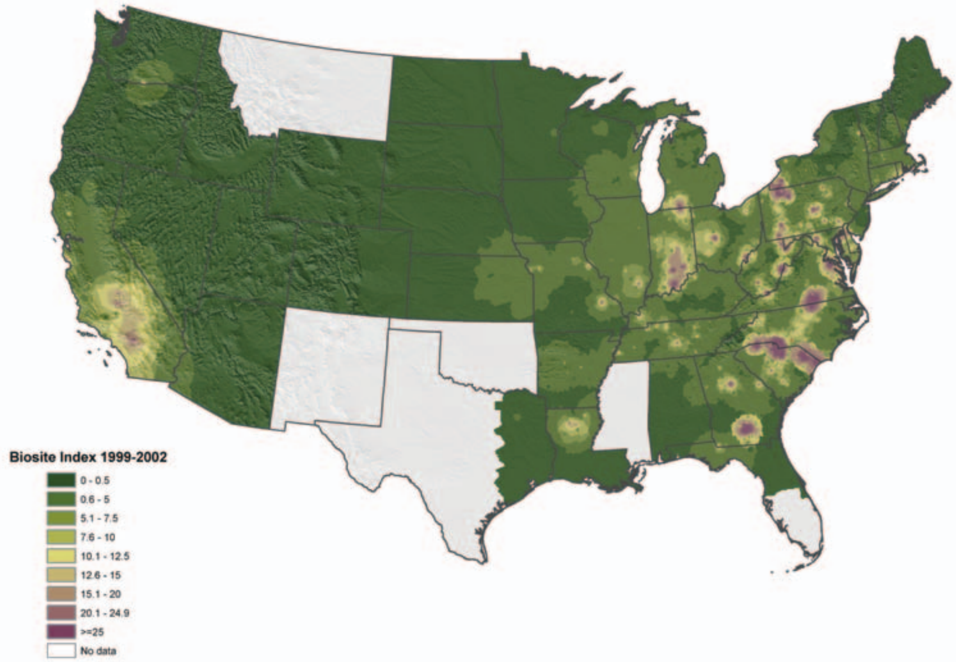
Table 3: Ozone Biosite Index Categories, Risk Assumption, and Possible Impact

Biosite Index	Bioindicator Response	Assumption of Risk to Forest Resource	Possible Impact
0 to < 5.0	Little or No Foliar Injury	None	Visible injury to isolated genotypes of sensitive species; e.g., common milkweed, black cherry.
5.0 to < 15.0	Light to Moderate Foliar Injury	Low	Visible injury to highly sensitive species, e.g., black cherry; effects noted primarily at the tree level.
15.0 to < 25.0	Moderate to Severe Foliar Injury	Moderate	Visible injury to moderately sensitive species, e.g., tulip poplar; effects noted primarily at the tree level.
≥ 25	Severe Foliar Injury	High	Visible injury leading to changes in structure and function of the ecosystem.

Source: Smith, G.C. FHM second ozone bioindicator workshop – summary of proceedings. Unpublished manuscript. 12 p. On file with: USDA Forest Service, Forest Health Monitoring Program, P.O. Box 12254, Research Triangle Park, NC 27709

[8] Ambrose, MJ.; Conkling, B.L., eds. In press. Forest Health Monitoring 2005 national technical report. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station.

Figure 16: Average Annual Biosite Index by Ecoregion Section, 1999–2002



Note: Table 3 provides a description of each category in the Ozone Biosite Index.

Source: Forest Health Monitoring 2005 National Technical Report[9]

[9] Ambrose, MJ.; Conkling, B.L., eds. In press. Forest Health Monitoring 2005 national technical report. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station.